

FIG. 25 shows the working end **822** in a patient's heart with one side of the engagement plane **825** contacting the targeted tissue **tt** and the other side exposed to the flow of blood **B**. It can be understood that the tissue and fluid flow, while both being electrically conductive, will have substantially different impedance characteristics when exposed to electrical potential. Typically, the blood flow about one side of the working end **822** will absorb and subtract heat from the region. In using a prior art Rf working end for catheter ablation, the electrode portion in contact with tissue will deliver energy to the contacted tissue, but at the same time heating blood in contact with the electrode. A typical prior art Rf working end uses thermocouples and feedback circuitry to modulate power as mean for controlling temperature. Since the prior art thermocouples measure temperature of the electrode—not actual tissue temperature—the system's controller cannot determine whether the electrode portion that actually contacts the tissue is at the desired temperature. At best, the thermocouple will signal an approximate temperature that is somewhere between the temperature of the blood and the contacted tissue. It is this uncertain electrode temperature in prior art catheters that can easily result in localized high power densities that create eschar and emboli.

The working end **822** of FIG. 25 is adapted to overcome the problems of prior art Rf catheters by insuring that transient high energy densities cannot occur in the fluid environment. The portion of the engagement plane indicated at **825'** can be wedged into substantial contact with the tissue by any suitable means known in the art (e.g., articulating portions, shape-memory materials, balloons, etc.). Another portion of the engagement plane indicated at **825''** is exposed to circulating blood. The sectional view of FIG. 26 indicates the use of an NTC variably resistive material **840B**. In other words, the NTC material becomes substantially conductive at its selected switching range, for example any selected temperature between about 60° C. and 90° C. At the switching range, the resistance of the NTC material **840B** will drop from a high base resistance to a very low resistance (the opposite of FIG. 7A). In operation, the working end will apply active Rf energy to the targeted tissue **tt** through engagement plane portion **825'** at a lower level until that portion is elevated in temperature to its switching range by contact with the heated tissue. Thereafter, such active energy application will be maintained or enhanced. At the same time, the blood circulation would cool the portion of the engagement plane indicated at **825''** that is not in contact with the tissue. Thus, the portion of the NTC material **840B** that underlies engagement plane portion **825''** will remain at a high base resistivity and substantially prevent the

application of energy to the blood. By this means, effective application of energy to the targeted tissue can be maintained—while at the same time blood will not be coagulated about the working end. Further, all these objectives can be achieved without relying of thermocouples, feedback circuitry and power controllers.

The NTC matrix **840B** can be fabricated of carbon and a zirconium oxide paste, for example, from about 5% to 50% carbon and 95% to 50% zirconium oxide. More preferably, the matrix can be from about 10% to 30% carbon and the balance of zirconium oxide. In one embodiment, the NTC matrix is preferably between about 10% to 12% carbon and 88% to 92% zirconium oxide. It is believed that an elevation of the temperature of the matrix decreases its resistance by slight thermal expansion of the carbon particles that reduces the effective distance between the conductive particles thereby enhancing electrical conduction through the matrix.

The above-described operation of a Type “G” probe in a fluid environment explains the advantages of an NTC matrix to assure active tissue heating when the fluid volume is substantial or dynamic, thus subtracting heat from the region of the working end. A similar probe working end can be used advantageously in a different fluid environment wherein the fluid is not circulating or the fluid is highly conductive. As an example, an orthopedic workspace can have a limited volume of saline therein while performing an arthroscopic procedure. The PTC material in a probe working end similar in form to FIGS. 25-26 will substantially terminate active RF heating of the fluid as the engagement surface **825**’ (see FIG. 26) reaches its switching range. At the same time, both active and passive energy application to the targeted tissue will be maintained through engagement surface **825**’ (see FIG. 26) as described in the Type “A” embodiment above.

Another Type “G” probe **800** and its method of use in a fluid environment is shown in FIG. 27. The working end **822** is carried at the distal end of a rigid probe body that can be used in an arthroscopic procedure. In one example, the targeted tissue **tt** is the surface of a patient’s joint capsule that is “painted” with the engagement plane **825** of the working end **822**. Such a procedure can be used to shrink collagen in the joint capsule to tighten the joint, such as in a patient’s shoulder.

FIG. 27 illustrates that probe **800** has a body portion **826** that is proximal to the engagement plane or surface **825**. In one embodiment, the exterior surface **827** of body portion **826** is an insulative material indicated at **828**. An

interior body portion of the working end **822** is of a variably resistive matrix **840B** as described previously. A conductive body portion **840C** (or electrode) at the interior of the probe is connected to a voltage source as described previously.

The matrix **840B** can be a PTC or NTC material, and in one embodiment is a rigid ceramic-type PTC material that is temperature sensitive. Of particular interest, an exterior layer **850** of a pressure-sensitive resistor is carried about the working end in contact with the variably resistive matrix **840B**. The variably resistive layer **850** can be substantially thin and fabricated as previously described, for example, using Product No. CMI 118-44 available from Creative Materials Inc., 141 Middlesex Rd., Tyngsboro, MA 01879. In the illustration of the probe's method of use in FIG. 27, it can be understood that any pressure against the pressure-sensitive resistive layer **850** will locally decrease its resistance to current flow therethrough. Thus, as the engagement plane **825** is painted across tissue the joint capsule with a fluid **F** in the workspace, Rf current will only flow through the localized engagement plane portion indicated at **825'** where the pressure-sensitive resistive layer **850** is under pressure which lowers its resistance substantially to thereby allow current flow therethrough. The illustration of FIG. 27 assumes the probe causes highly localized *active* Rf heating in the tissue while operating in a mono-polar manner in cooperation with a ground pad (not shown). In operation, the probe working end will thus apply energy to tissue only at the point of contact and pressure with the engagement plane. The fluid **F** and collateral tissue regions will not be subject to ohmic heating. It should be appreciated that the probe also can operate in a bi-polar manner wherein the probe working end carried an opposing polarity electrode, e.g., about the exterior surface **827** of the probe (see FIG. 27). In this embodiment, the variably-resistive matrix **840B** can modulate current flow exactly as described in previous embodiments to maintain the tissue temperature in contact with the engagement plane portion **825'** at, or within, a selected temperature range.

It should be appreciated that the scope of the apparatus and method of the includes the use of a probe that does not carry a body portion of a variably-resistive matrix. In other words, the working end can rely only on the pressure-sensitive resistive layer **850** about the engagement plane **825** to locally apply energy to engaged tissues (see FIG. 27).

In another embodiment (not shown), the working end of the probe can have an elongate core of the substantially resistive material, e.g., either in a rod-like member or in a helical member. This resistive material has a *fixed* resistivity

and is adapted to pre-heat the working end and the engaged tissue as a means of pre-conditioning certain tissues to have a